Copy 5

CONFIDENTIAL

RM A55K14

C.1

NACA RM A55K14

NACA

RESEARCH MEMORANDUM

EFFECT OF AREA-SUCTION-TYPE BOUNDARY-LAYER CONTROL ON THE LANDING-APPROACH CHARACTERISTICS OF A 35° SWEPT-WING FIGHTER

By George E. Cooper and Robert C. Innis

Ames Aeronautical Laboratory
Moffett Field, Calif.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

February 3, 1956

CONFIDENTIAL

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

EFFECT OF AREA-SUCTION-TYPE BOUNDARY-LAYER CONTROL ON THE LANDING-APPROACH CHARACTERISTICS OF A 35° SWEPT-WING FIGHTER

By George E. Cooper and Robert C. Innis

SUMMARY

This report presents results of evaluation flights of F-86 series aircraft equipped with two types of boundary-layer control differing significantly with regard to the type of lift increment produced. In one case, application of boundary-layer control to the wing leading edge increased maximum lift coefficient $C_{L_{max}}$ significantly by delaying stall to higher angles, but provided no change in lift at a given attitude. In contrast, application of boundary-layer control to the trailing-edge flaps increased the flap lift increment at attitudes below $C_{L_{max}}$, but resulted in only a small increase in $C_{L_{max}}$.

The report presents the comments of 16 Air Force, Navy, contractor, and NACA pilots as to the reasons for their choice of minimum, comfortable approach speed on the several configurations tested. These pilots' opinions are analyzed in relation to the characteristics of the airplanes in an attempt to isolate the aerodynamic factors of primary importance in establishing landing-approach speeds.

INTRODUCTION

Application of boundary-layer control to airplanes has indicated that two types of lift increment may be obtained. As indicated in reference 1, application of boundary-layer control to the leading edge of a swept wing increased $C_{L_{max}}$ significantly by delaying stall to higher angles, but provided no change in the lift at a given attitude. In contrast, application of boundary-layer control to the trailing-edge flaps of the same wing increased the flap lift increment at attitudes below $C_{L_{max}}$, but resulted in only a relatively small increase in $C_{L_{max}}$. (See ref. 2.)

In order to obtain some flight experience with these two types of boundary-layer control, two F-86 airplanes were modified. One airplane (an F-86F) was equipped with porous suction boundary-layer control along the wing leading edge. The other airplane (an F-86A-5) was equipped with trailing-edge flaps having porous suction boundary-layer control near the flap leading edge. Evaluation flights on these airplanes were flown by 16 Air Force, Navy, contractor, and NACA pilots, and the effects of these applications of boundary-layer control on the flight characteristics of these airplanes were determined. The specific results dealing with lift increments obtained, flow requirements, and installation details have been reported in references 3 and 4. It is the purpose of this report to examine the relationship between the pilots' opinions of the several configurations flown and their choice of minimum, comfortable landing-approach speed.

NOTATION

A_x	longitudinal acceleration
A_z	normal acceleration
B.L.C.	boundary-layer control
c	wing chord
C_D	drag coefficient
C_L	lift coefficient
$C_{L_{max}}$	maximum lift coefficient
C.L.E.	cambered leading edge
D	drag
F_G	gross thrust
F_R	ram drag
I.A.S.	pilots' indicated airspeed as read from cockpit indicator, knots
$\frac{L}{D}$	lift-to-drag ratio
q	dynamic pressure
V_A	calibrated approach airspeed, knots

V_S calibrated stalling airspeed, knots

$V_{C_{L_{max}}}$ calibrated airspeed corresponding to maximum lift coefficient, knots

$\left(\frac{W}{S}\right)_A$ wing loading for approach condition (1000 lb of fuel remaining)

α angle of attack of fuselage reference line

DESCRIPTION OF TEST AIRPLANES

Three slightly different models of the F-86 airplane were used in this program. The first, a standard F-86A-1, shown in figure 1, was equipped with leading-edge slats and 38° slotted flaps, and was flown by most of the evaluating pilots to provide a basis for more direct comparison between the standard airplane and those equipped with boundary-layer control. Unfortunately, this model had several undesirable features that were not representative of the standard F-86A-5 and later versions. These included: a different leading-edge slat which provided a greater $C_{L_{max}}$ but really did not provide a corresponding decrease in usable stalling speed because of an undesirable pitch-up preceding the stall; a pilot's airspeed indicator which was unreliable below approximately 102 knots; and excessive friction in the longitudinal control system.

The second airplane was an F-86A-5 model, a photograph of which is included as figure 2. Suction for the flap boundary-layer control was obtained from a simple ejector pump (mounted below the fuselage) utilizing air bled from the twelfth stage of the jet-engine compressor. Suction was controlled by a switch in the cockpit which actuated a shutoff valve in the bleed line. This airplane was very similar to the first in that both were equipped with power-boosted ailerons and elevator controls, but differed in that the flap deflection was increased to 55° and porous area suction was applied near the flap leading edge. In addition, the leading-edge slats were replaced by cambered leading edges (refs. 5 and 6) equipped with 0.20c wrap-around fences (0.05c height) at the 63-percent span location. This combination gave approximately the same stall speed as the normal airplane with slats and 38° flaps.

Upon completion of the evaluation of the second airplane, improved flap lift characteristics were obtained by refairing the flap-fuselage junction and changing to a porous material having graded porosity. In addition, a diffuser was added to the ejector pump which increased the speed range over which full flap lift increment was realized for a 64° flap deflection. This configuration may be seen in figure 3. Several wing flap and wing leading-edge combinations were investigated after these changes were made. These included the 55° flap with the wing leading edge cambered and no fence, 55° flap with the wing leading-edge slat, 64° flap with the wing leading edge cambered plus a fence, and 64° flap with the wing leading-edge slat.

The third airplane, shown in figure 4, was an F-86F model on which the leading-edge slats were replaced by leading edges of the same profile containing a porous strip extending over essentially the complete span and through which the boundary-layer air was drawn. Suction for the leading-edge boundary-layer control was obtained from a modified turbo-supercharger mounted beneath the fuselage and driven by air bled from the twelfth stage of the jet-engine compressor. Besides a switch for actuating a shutoff valve in the suction line, the cockpit controls included buttons on the control stick to increase and decrease rpm, which modulated the bleed air to the turbo and hence controlled the turbo rpm and amount of suction. A more complete description of this porous area-suction installation may be found in reference 3. In contrast to the F-86A model, this airplane (F-86F) incorporated irreversible power-operated ailerons and linked elevator and stabilizer (flying tail), each with artificial feel. The major effect of these two different control systems was that, with the latter one, the maneuvering control forces were considerably higher in the landing-approach speed range than with either of the F-86A airplanes. With the artificial-feel system, positive longitudinal stick-free stability was present throughout the approach, whereas on both F-86A airplanes the stick-free stability was essentially neutral at approach speeds.

TEST PROCEDURE

The initial phase of the investigation was flown by a total of 16 Air Force, Navy, contractor, and NACA pilots. Each pilot flew at least one flight in each of the airplanes with boundary-layer control, and several pilots made two or three flights per airplane. Most of the pilots also flew one flight in the standard F-86A-1 equipped with 38° flaps and leading-edge slats. Each pilot was requested to furnish the following information on each different configuration flown: stall speed, stall characteristics and opinion of stall, the minimum comfortable approach speed at landing weight,[1] and the primary reasons for choosing that particular approach speed. (These data are summarized in table I for each pilot.) The Navy and NACA pilots made their evaluation based on the requirements for a carrier approach and landing. For this purpose, field carrier landings were made with most of the configurations at Crows Landing Auxiliary Landing Field with the aid of a Navy Landing Signal Officer. The Air Force pilots, in general, made 360° overhead, partial power, sinking-type approaches, which started at approximately 1,000 feet altitude over the touchdown point.

[1]Landing weight as used herein is defined as the gross weight with 1000 pounds of fuel remaining.

While the carrier type of approach may be defined by a single approach speed, it was noted that with the sinking approach at least three different speeds at different points in the pattern were considered necessary by most pilots to define adequately any given approach. These are: the speed when turning onto final approach, the speed "over the fence" (which generally coincides with the point at which the pilot begins his round out), and the touchdown speed. For reasons of simplicity and comparison in those cases where three speeds were given, only the over-the-fence speed has been used as it was found to be more similar to the carrier-approach speed.

A later phase of the investigation comprised field carrier landing-evaluation flights of the suction-flap airplane with the improvements (fig. 3) and several leading-edge combinations. This phase of the evaluation was conducted by the four NACA research pilots who also took part in the initial evaluation.

It is noted in table I that most pilots tended to report approach speeds to the nearest 5 knots or in ranges of airspeed such as 105 to 108 knots. This fact probably arises from pilot reluctance to rely on the airspeed indicator closer than 2 to 3 knots, as well as the feeling that the approach speeds given were average values because of the variation in wing loading, which normally changed about 10 percent during the course of an evaluation flight.

In the calculation of the measured stalling speeds and thrust-required curves, the value of wing loading used for each airplane was that corresponding to 1000 pounds of fuel remaining. This is given below for each test airplane.

Standard airplane	42.3 lb/sq ft
Suction flap airplane	42.6 lb/sq ft
Suction leading edge airplane	44.7 lb/sq ft

The value of gross weight for which many of the pilots reported stalling speeds was not accurately known. This factor undoubtedly contributed to the scatter in the reported stalling speeds, as well as to the differences between reported stalling speeds and the measured values based on $C_{L_{max}}$. For the standard airplane, this discrepancy is further aggravated by an unreliable but large error in indicated airspeed below about 102 knots. Consequently, the measured value of stall speed has been used for all comparative purposes.

An airspeed calibration was obtained in flight for all three airplanes covering their approach speed ranges to allow correlation between pilot-reported speeds on the different airplanes as well as to allow proper correlation between speeds reported by the pilot and the various measured quantities.

Recorded airspeed for all three test airplanes was obtained using an identical system. This consisted of an NACA swiveling pitot static head mounted on the tip of a 96-inch nose boom and may be seen in figures 2 and 3. Also visible in these figures is the offset located near the tip of the nose boom which contained a flow-angle vane for measuring angle of attack. For pilot-opinion flights the standard pilots' airspeed indicator system was used on both the standard F-86A-1 and the F-86F equipped with leading-edge boundary-layer control. These systems comprised, for the standard F-86A-1, a total-pressure source located in the engine duct and a static-pressure source on the side of the fuselage, while for the F-86F, both total and static pressures were obtained from a pitot static head located on the right wing-tip boom. For the suction flap F-86A-5 airplane, the pilots' airspeed indicator was connected directly to the swiveling head which had been used for the recording system.

Calibration of the standard F-86A-1 and the F-86F was obtained by comparing the pilots' indicated airspeed with the recorded airspeed. Since on the F-86A-5 airplane, the same pitot-static source was used for both the pilots' indicated and recorded airspeeds, only instrument error would be expected. This was verified by pacing with the F-86F down to 95 knots indicated airspeed. A check of the standard F-86A-1 was also made in this manner down to 105 knots. At speeds below about 102 knots, this airspeed system had a large error and was severely affected by small pitch changes.

With the exception of table I, which gives pilot-reported stall and approach speeds in terms of the pilots' indicated airspeed, all other airspeed values are calibrated speeds and were obtained from pilots' indicated speeds using the flight-determined calibration curves of figure 5.

DATA REDUCTION

The lift and drag data were obtained in steady flight at constant values of engine rpm corresponding to approach power settings.

The equations used to determine the lift coefficients and drag coefficients are as follows:

$$C_L = \frac{W}{qS}\left(A_z\cos\alpha + A_x\sin\alpha\right) - \frac{1}{qS}\left(F_G\sin\alpha\right)$$

$$C_D = \frac{W}{qS}\left(A_z\sin\alpha - A_x\cos\alpha\right) + \frac{1}{qS}\left(F_G\cos\alpha - F_R\right)$$

In the equations above, the first portion is for the accelerations on the airplane, while the second portion is for the thrust force acting on the airplane and the force caused by turning the air at the inlets. The gross thrust and engine air flow were determined from measurements of the total pressure and temperature in the tail pipe of the jet engine.

Measured stalling speeds were determined using the measured values of $C_{L_{max}}$ with a correction for thrust based on the thrust required at the approach airspeed.

Thrust-required curves were determined at landing weight for each configuration by the following relationship:

$$\text{Net thrust from the engine required for level flight} = \frac{D}{\cos\alpha}$$

RESULTS

Initial Investigation

The effects of applying area suction to either the flap or the wing leading edge, in terms of lift coefficient and angle of attack, may be seen in figure 6 for the airplanes flown in the initial investigation. Also shown is the effect of increasing flap deflection from 38° on the standard airplane to 55° on the suction-flap airplane. This comparison is of interest, but because of the undesirable features that were previously pointed out as existing on the standard F-86A-1 airplane, it is not considered as reliable as those made between the various boundary-layer control configurations. The lift coefficient corresponding to each pilot's approach speed has been shown on these curves in order to indicate the range of angles of attack being used.

The opinions of each of the 16 evaluation pilots, relating to the stalling and landing-approach characteristics, as indicated earlier, may be found in table I. The stall data have been condensed and compiled into table II, while a compilation of the minimum comfortable approach speeds (or over-the-fence speeds) chosen by each pilot is given in table III. Comparative figures are listed showing the effects of suction alone and of increased flap deflection, as well as comparisons with the standard airplane. While considerable variation existed in the individual pilot's choice of the minimum, comfortable approach speed, it is felt that the decreases in approach speeds noted are valid.

The primary reason given by each pilot for choosing his approach speed is given in table IV for each configuration flown. Curves of thrust required for level flight plotted against airspeed are presented in figure 7 for those configurations flown in the initial investigation.

The average approach speed chosen by the pilots is shown on these curves to enable comparison with the minimum-thrust-required speed.

The relationship between approach speed and stalling speed for the configurations flown in the initial phase are presented below.

Configuration	$\frac{V_A}{V_{C_{L_{max}}}}$
I Standard airplane	1.33
II Suction-flap airplane	
Suction off	1.23
Suction on	1.19
III Suction leading-edge airplane	
Suction off	1.21
Suction on	1.29

Later Investigation

The lift versus angle-of-attack data for the additional suction-flap configurations (IV through VII) flown in the later investigation are presented in figure 8. The pilot-opinion data for these configurations are included in table V. (Also included for comparison are the data from the initial phase for the four pilots who flew all configurations.) The ratios of approach speed to stalling speed are shown in this table for these pilots and all configurations flown.

The primary reason given by each of these pilots for limiting his approach speed was given in table IV, along with the reasons given in the initial phase. Thrust-required versus airspeed curves are presented in figure 9 for the suction-flap airplane with leading-edge slats, and with either a 55° plain flap or a 64° plain flap. The relationship between pilot-approach speed and the speed for minimum thrust required is shown in figure 10 for all configurations flown.

DISCUSSION

There is a wide variety of factors which may be considered by a pilot as affecting his choice of minimum comfortable approach speed. It is possible, and often the case, that several factors are present for one airplane, making selection of a single primary reason difficult because of complex interrelationships. An attempt has been made here, however, to isolate those factors considered of primary importance by the pilots.

Examination of table IV indicates that reasons assigned by the pilots for limiting the approach speed of the various airplanes can be divided into three categories, as follows:

guide on α

A. Reasons associated with stall characteristics: It would be expected that on airplanes limited by this characteristic the most direct influence on the approach speed would result from an increase in $C_{L_{max}}$ or improvements in the stalling characteristics.

B. Reasons associated with attitude or visibility limitations: It would be expected that on an airplane limited by this characteristic the most direct influence on approach speed would result from an increase in lift at attitudes below $C_{L_{max}}$.

C. Reasons associated with longitudinal control, that is, ability to control altitude or flight path: A number of factors influence this characteristic. One expected to be of primary importance, which was varied on the test airplanes, was the variation of L/D with α. This variation is most evident from the flight data by the change in the shape of the curve of thrust required for steady level flight versus speed (figs. 7 and 9).

It is of interest to examine the above listed anticipations in comparison with the approach speed decrements realized from the two different types of boundary-layer control.

The F-86F with boundary-layer control applied to the leading edge falls definitely into Category A with suction off, since $C_{L_{max}}$ was less than that of any of the configurations tested (fig. 6(b)) and table IV shows that 13 of the 16 pilots who flew this airplane limited their approach speed because of proximity to the stall or yaw. The application of leading-edge boundary-layer control to the F-86F increased $C_{L_{max}}$ by 0.60, and the corresponding stall speed was reduced 22.2 knots. As a result, only one pilot tended to consider proximity to the stall a limiting factor although 3 were influenced by poor stall characteristics. The average reduction in approach speed was 20.2 knots, only slightly less than the reduction in V_S. From the pilots' comments it is apparent that a new limiting factor was introduced, attitude or visibility (Category B), which prevented the full utilization of the $C_{L_{max}}$ increment. Thus, although leading-edge boundary-layer control postponed the angle of attack for $C_{L_{max}}$ by as much as 10°, only 5° of this increase was actually used.

Flight of this airplane with boundary-layer control operating also revealed an undesirable characteristic which may be pertinent in the use of any type of boundary-layer control that requires maintenance of considerable power for its operation. When making sinking-type approaches, the pilots found it impossible to slow up below 115 knots without reducing engine rpm below that required to maintain adequate boundary-layer control. With the carrier-type approach, this was not a problem as approximately 80-percent rpm was required in this approach, and a significant increase in $C_{L_{max}}$ was available as shown in figure 6.

The F-86A with boundary-layer-control flaps does not present as clear-cut a case as does the F-86F. The 16 pilots who flew this airplane were almost evenly divided in their reasons for limiting approach speed with boundary-layer control inoperative: 7 considered proximity to the stall (Category A) the limiting factor; 5 considered visibility and attitude (Category B) the limiting factor; and 6 considered the longitudinal control (Category C) the limiting factor.

On the basis of the results presented in figure 6(a) it would be expected that application of boundary-layer control to the flap would tend to be relieving with respect to attitude and visibility rather than stall speed (a ΔV_S of only 1 knot). The pilots' comments are consistent with these changes in that, with boundary-layer control operating, only two considered the attitude or visibility the limiting factor. The average decrease in the approach speed was 5.9 knots. Closer examination of this average, however, reveals that the pilots who previously considered Category B or C the limiting factor benefited most from the operation of boundary-layer control to the extent of a 7.9-knot decrease. The pilots who previously had considered proximity to the stall the limiting factor benefited the least to the extent of 3.0 knots. Thus, despite the lack of any dominant limiting factor on this airplane, there is a consistent relationship between the effect of aerodynamic change and the factors which the individual pilot considered limiting on choice of approach speed.

The aerodynamic factors which influence the ease with which the attitude or flight path of the airplane can be controlled are more complex than the Category A and B limitations. However, on all but one of the configurations tested, the average minimum approach speed chosen bears a consistent relationship to the speed for minimum thrust (figs. 7, 9, and 10). For all cases except that with leading-edge boundary-layer control on (fig. 7(b)), the minimum approach speed lies slightly above the speed for minimum thrust required. In this one case, however, the flatness of the curve in this region makes the minimum-thrust point much less clearly defined. This relationship possibly reflects the pilots' reluctance to fly on the "back side" (below speed for minimum thrust) of the thrust-required versus speed curve. It can be reasoned that, at speeds below this minimum-thrust point, the ability to flare or arrest sink rates deteriorates below the minimum acceptable to the pilot and tends to result in his setting his approach speed accordingly. This surmise is not explicitly borne out by the pilots' comments, but it will be observed from table V that the decreases in average approach speed due to boundary-layer control on the flap are related very closely to the corresponding decreases in speed for minimum thrust required. It is noteworthy that the research pilots (K, L, M, and N) who had the most opportunity to fly the test airplanes, were consistent in noting Category C as the primary limiting factor establishing the approach speeds on all the flap boundary-layer-control configurations. Category C is also considered as the limiting factor for the standard F-86A-1 by 7 out of 12 pilots.

Of the additional configurations flown having flap boundary-layer control (see table V), it is of interest to note that configuration IV, (C.L.E. no fence) had an unsatisfactory roll-off at the stall but fell in Category C rather than Category A. Configuration V, having excellent stall characteristics, was also limited by Category C and was generally considered the most desirable configuration flown, although it did not result in any appreciable decrease in approach speed over configuration IV. A slightly greater decrease in approach speed resulted from increasing the flap deflection to 64°, but the increased drag resulted in less desirable wave-off characteristics.

CONCLUDING REMARKS

Evaluation flights by 16 pilots of an F-86F airplane equipped with an area-suction leading edge and an F-86A-5 equipped with an area-suction flap indicated significant reductions in the minimum comfortable landing-approach speed were possible with addition of boundary-layer control. Leading-edge boundary-layer control was most effective in providing a large reduction in both stalling speed and approach speed together with an increased margin of lift for flare and maneuvering during the approach. Further reduction in approach speed was limited primarily by visibility and attitude considerations. While flap boundary-layer control reduced the stall speed only slightly, it reduced the airplane attitude required to obtain a given lift and therefore affected reduction in approach speeds for those pilots giving visibility and attitude or longitudinal control as the limiting factor. Although each boundary-layer-control application resulted in a favorable change in the shape of the thrust-required versus speed curve (a reduction in speed for minimum thrust required), the suction-flap case was most indicative of a close relationship between the limitation of longitudinal control (or ability to control altitude or flight path), the pilot's minimum approach speed, and the speed for minimum thrust required. The pilots' reluctance to fly below the speed for minimum thrust therefore appears associated with the loss in longitudinal control and ability to control altitude or flight path.

Additional research on a variety of aircraft should be carried out in order to relate the primary limitation on approach speed established by the pilot to aerodynamic characteristics of each airplane.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, Calif., Nov. 14, 1955

REFERENCES

1. Holzhauser, Curt A., and Martin, Robert K.: The Use of Leading-Edge Area Suction to Increase the Maximum Lift Coefficient of a 35° Swept-Back Wing. NACA RM A52G17, 1952.

2. Cook, Woodrow L., Holzhauser, Curt A., and Kelly, Mark W.: The Use of Area Suction for the Purpose of Improving Trailing-Edge Flap Effectiveness on a 35° Sweptback Wing. NACA RM A53E06, 1953.

3. Bray, Richard S., and Innis, Robert C.: Flight Tests of Leading-Edge Area Suction on a Fighter-Type Airplane With a 35° Sweptback Wing. NACA RM A55C07, 1955.

4. Anderson, Seth B., and Quigley, Hervey C.: Flight Measurements of the Low-Speed Characteristics of a 35° Swept-Wing Airplane with Area-Suction Boundary-Layer Control on the Flaps. NACA RM A55K29, 1956.

5. Anderson, Seth B., Matteson, Frederick H., and Van Dyke, Rudolph D., Jr.: A Flight Investigation of the Effect of Leading-Edge Camber on the Aerodynamic Characteristics of a Swept-Wing Airplane. NACA RM A52L16a, 1953.

6. Anderson, Seth B.: Correlation of Flight and Wind-Tunnel Measurements of Roll-Off in Low-Speed Stalls on a 35° Swept-Wing Aircraft. NACA RM A53G22, 1953.

TABLE I.- PILOTS' COMMENTS RELATING TO STALL AND APPROACH CHARACTERISTICS

(a) Configuration I: Standard F-86A-1; 38° flap; slats

Pilot	Suction B.L.C.	Stall speed, I.A.S., knots	Stall characteristics	Approach speed I.A.S., knots	Primary reasons for choosing approach speed
A	-	98-100	Warning: Lightening of stick forces. Stall: Satisfactory. Mild pitch-up and roll-off.	115	Visibility is limiting factor. Have good control down to 105, but attitude best at 115-120. At about 100 much larger stick movement is necessary for control. Approach speed dependent upon gustiness.
B	-	98	Warning: Marginally satisfactory. Force lightening at 105-102 and pitch-up at 102. No aerodynamic warning. Stall: Satisfactory. Mild buffet, left roll-off, easy to control. Ailerons more effective than elevator at stall.	115	115 chosen to give adequate speed above stall (in this case 105 where force lightening occurred). L.S.O. (Landing Signal Officer) would add 15 to stall for approach speed. Pilot chooses a minimum of 10. Airplane flyable at any speed above stall. Elevator control good at 110. At 110-115 visibility is a problem but would not be if seat could be raised. Considerable floating experienced at 115.
E	-	102	Warning: None. Stall: Slight pitch-up; left wing drop, incipient spin.	130 on final 120 over fence	Forward visibility.
F	-	97-101	Warning: Insufficient. Stall: Satisfactory. Moderate pitch-up and roll-off.	115	Poor lateral control and normal margin for flare out. Better lateral control and feel on suction flap airplane. Worse sink rate than suction flap airplane suction on.
G	-	99	Warning: Light buffet 110. Yaws left at 103 but controllable. Stall: Very good. Slow left wing drop.	130 on final 120 over fence 110 touchdown	Pattern felt comfortable by touching down at 110 with no buffet or yaw.
H	-	100	Warning: Good. Light buffet and pitch-up at 105. Stall: No comments.	130	Limited by visibility and feel of aircraft. Lack of adequate seat adjustment restricts visibility over nose more than on suction-flap airplane. Less able to rack around at 120 than suction-flap airplane.
I	-	100	Warning: Good. 3-6 above stall. Stall: Good to excellent.	125 over fence 115-110 on touchdown.	Comfortable attitude, visibility. Not worried about hitting tailpipe.
K	-	100	Stall: Satisfactory.	120	Decrease in ability to control altitude by longitudinal control alone.
L	-	100	Stall: Satisfactory. Mild pitch-up and roll-off.	120	Loss of longitudinal control. No stick centering from trim at approach speed.
M	-	101-102	Stall: Unsatisfactory. Due to pitch-up.	115	Positive altitude control.
N	-	101	Warning: Unsatisfactory. Very little. Stall: Satisfactory.	115	No comment.

TABLE I.- PILOTS' COMMENTS RELATING TO STALL AND APPROACH CHARACTERISTICS - Continued

(b) Configuration II: F-86A-5; 55° suction flap; C.L.E. plus fence

Pilot	Suction B.L.C.	Stall speed I.A.S., knots	Stall characteristics	Approach speed I.A.S., knots	Primary reasons for choosing approach speed
A	Off	100	Warning: Weak Buffet. Stall: Very satisfactory. Mild pitching, very gentle.	115	Proximity to stall. Good control 100 up. Good visibility 115-118. No noticeable difference between suction on and off.
	On	100		115	
B	Off	100	Warning: Too close but adequate. Stall: Mild, satisfactory.	115	Limited by visibility at 110. Control is satisfactory right down to stall. Longitudinal control too sensitive at approach speeds. More positive stick-free stability as on F-86F is more desirable.
	On	95-98	Warning: Too close but adequate. Stall: Mild, satisfactory.	108	Limited by nearness to stall. Visibility was not limiting at 110. Attitude is more desirable with suction on, but without lower stall speed, would not lower approach speed.
C	Off	100	Stall: Satisfactory.	125	Minimum positive control for gusts or emergency.
	On	95	Stall: Good	115	Has better control and stability than with suction off. No visibility problem.
D	Off	100	Warning: Buffeting, slight wing roll. Stall: Satisfactory.	140 base 120 over fence 110 touch down	Adequate speed above stall. Feels comfortable at 110. Satisfactory stall allows coming to within 10 of stall.
	On	99	Warning: Buffeting and slight wing roll. Stall: Satisfactory.	140 base 120 over fence 105 touch down	Adequate speed above stall. Decreased attitude allows lower touchdown speed. Visibility not a problem at base and final approach speeds used but noticeably improved on touchdown.
E	Off	98	Warning: High angle of attack, shaking and wallowing of airplane at 102 (more than suction on). Stall: Satisfactory, nose drops through.	125-130 on final 115-120 over fence	Optimum visibility with more than adequate airspeed. No control difficulties.
	On	97	Warning: None Stall: Satisfactory. Consists of wing drop which is controllable but worse than suction off. Inconsistent: wing drops or stalls straight ahead.	115 on final 105 over fence	Decrease in approach speed due to better visibility. Not limited otherwise. Possibly could use 110 approach speed on final. Over fence speed limited by fear of dragging tail.
F	Off	92-97	Warning: Good (100-103). Stall: Satisfactory. Pitch-up followed by pitch-down.	115	Limited by concern about ability to flare and the time spent in transition-power off.
	On	90-94	Warning: Inadequate. Stall: Satisfactory.	110	Limited by lack of stall warning. Like increased visibility with suction. Suction also reduces rate of sink. Flared better than anticipated but may have been influenced by carrying more power than usual. Flies better 5-10 above stall than suction off.
G	Off	101	Warning: O.K. Burble at 115, slight left yaw at 102. Stall: Satisfactory. Slight left roll tendency.	130 on final 120 over fence 110 touchdown	Limited by speed above yaw and stall. Sink rate higher than suction on.
	On	99	Warning: Satisfactory. Light buffet at 105. Stall: Satisfactory. Straight ahead.	120 on final 115 over fence 105 touchdown	Limited by speed above stall. Speed on base and final very comfortable 120 kts. due to increased ability to turn. Feels better suction on, especially in jet wash (i.e., turbulence). Could tighten pattern suction on. Decrease in attitude very significant, may influence reduction in approach speed.

TABLE I.- PILOTS' COMMENTS RELATING TO STALL AND APPROACH CHARACTERISTICS - Continued

(b) Configuration II: F-86A-5; 55° suction flap; C.L.E. plus fence - Concluded

Pilot	Suction B.L.C.	Stall speed I.A.S., knots	Stall characteristics	Approach speed I.A.S., knots	Primary reasons for choosing approach speed
H	Off	99	Warning: Satisfactory. Light buffet. Stall: Satisfactory.	115	Limited by proximity to stall. Added flap deflection 55° over 38° quite apparent, gave large improvement, more than that due to effect of suction.
	On	94-97	Warning: Light to moderate buffet; more than suction off. Stall: Satisfactory.	110	Limited by general feel in approach. Decrease in sink rate with suction on. A more solid feel, especially in turns. Decrease in attitude quite noticeable. Not limited by nearness to stall.
I	Off	100-101	Warning: Good. Buffet 3 less than normal F-86.	125 (power on approach)	Comfortable attitude. Not worried about proximity to stall.
	On	98	Warning: Good. Buffet 3 less than normal F-86.	115 over fence 110 touchdown	Speed above stall. Attitude improved. Maneuvering in approach felt better.
J	Off	100	Warning: Wing drop and buffet 2 or 3 above stall.	120	Attitude. Sufficient speed above stall.
	On	97	Warning: Sufficient. Right wing drop and buffet. 2 or 3 above stall.	115	Feels comfortable. Proximity to stall. With more power on would be comfortable at 110.
K	Off	95	Stall: Satisfactory.	115	Decrease in ability to control altitude by longitudinal control alone. Visibility.
	On	90	Stall: Satisfactory.	108	Decrease in ability to control altitude by longitudinal control alone. Visibility improved over suction off but becomes contributing factor again at this lower speed.
L	Off	95	Warning: Satisfactory. Buffet 3-4 before stall. Stall: Satisfactory. Mild pitch-up, straight ahead.	115	Loss of longitudinal control or ability to adequately control altitude.
	On	90	Warning: Marginal. Buffet 2-3 before stall. Stall: Satisfactory. Mild pitch-up, straight ahead.	105-107	Loss of longitudinal control or ability to adequately control altitude.
M	Off	95-97	Warning: Marginal. Buffet 98. Stall: Satisfactory.	105-110	Ability to stop sink rate.
	On	92-95	Warning: Marginal. Buffet 98. Stall: Satisfactory.	100-105	Ability to stop sink rate.
N	Off	98	Warning: Marginal. Buffet at 106. Stall: Good.	110-115	Adequate margin above stall.
	On	98	Warning: Marginal. Buffet at 106. Stall: Good.	110-115	Adequate margin above stall. Visibility good suction on. Pilot noted no difference in approach speed suction on or off but did note improved visibility.
O	Off	98	Warning: Mild aileron buffet 102. Stall: Good except for mild pitch-up	120 on base 115 over fence 100 touchdown	Ability to pull g.
	On	92	Warning: Mild aileron buffet 96. Stall: Good except for mild pitch-up.	110 on base 110 over fence 95 touchdown	Ability to pull g.
P	Off	100	Satisfactory	108	Proximity to stall.
	On	99	Satisfactory	104	Proximity to stall.

TABLE I.- PILOTS' COMMENTS RELATING TO STALL AND APPROACH CHARACTERISTICS - Continued

(c) Configuration III: F-86F; 38° flap; suction leading edge

Pilot	Suction B.L.C.	Stall speed I.A.S., knots	Stall characteristics	Approach speed I.A.S., knots	Primary reasons for choosing approach speed
A	Off	115	Warning: Unsatisfactory. Very mild, slight snaking, mild pitchup. Yaw at 125 too far ahead of stall to be considered as warning. Stall: Satisfactory.	135	Uncontrollable yaw at 125. Would pull nose over in approach.
	On	90	Warning: No comment. Stall: Left roll and pitch-down, unsatisfactory on first flight but satisfactory on all others.	105-108	Nose high attitude. Unreliable stall. Cut suction off at 90, airplane fell out and rolled. (Airplane stalled.)
B	Off	108-115	Warning: No comment. Stall: Buffets and shudders at 115 down to 108 before becoming uncontrollable and fully stalled. Usable stall speed is 115. No noticeable yaw at 120-125.	140	Should not be flown in approach below 130 because of early buffet and stall encountered in turning flight at 130.
	On	90-93	Warning: Nose-high attitude. Poor and unsatisfactory. Stall: No comment.	110	Visibility is primary factor in limiting approach speed. 115 gives better visibility than 110 but latter is marginally adequate. Pilot noted that one wing stalled first in turning flight. Was not concerned about possible loss of suction. Could reverse turn at 100. Control good down to stall.
C	Off	100	Warning: Fair. Objectionable yaw. Stall: Satisfactory.	128	(No actual approaches made.)
	On	90-92	Warning: Extreme angle of attack. Stall: Satisfactory.	120	Better control and stability.
D	Off	100-115	Warning: Heavy buffet at stall. Stall: Acceptable.	150 base 130 over fence 120 touchdown	(Higher stall speed apparently determines approach speed.)
	On	94	Warning: None. Stall: Acceptable.	130 base 110 over fence 110 touchdown	Visibility was limiting for approach and touchdown speed. Pilot liked ability to pull more g's in approach (140). Also liked decreased stall speed.
E	Off	105	Warning: Yaws at 120. Not too severe though. (Yaw too far ahead of stall to be considered as warning.) Buffet continues down to stall with pitching and continued buffet through the stall. Stall: Satisfactory.	135 on final 125 over fence	Adequate airspeed above yaw.
	On	98	Warning: No yaw. Stall: Satisfactory. Similar to suction off.	125 on final 110 over fence	Limited by visibility to 125. Otherwise could have been 115. Flight was smooth right down to stall at 98.
F	Off	108	Warning: Yaw at 121-123. Uncontrollable if not looking for it. Worse than normal F-86F. Continuous lateral oscillation to pitch-up and stall at 108. Stall: Unsatisfactory due to yaw and pitch-up.	125-130	Objectionable yaw at 121-123.
	On	98	Warning: None	110	Limited because of concern for dragging tail and loosing suction. Limited stall warning. Good control down to stall.

TABLE I.- PILOTS' COMMENTS RELATING TO STALL AND APPROACH CHARACTERISTICS - Concluded

(c) Configuration III: F-86F; 38° flap; suction leading edge - Concluded

Pilot	Suction B.L.C.	Stall speed I.A.S., knots	Stall characteristics	Approach speed I.A.S., knots	Primary reasons for choosing approach speed
G	Off	107	Warning: Good. Yaw and buffet at 125. Stall: No comment.	140 on final 130 over fence 120 touchdown	Limited by buffet, general aircraft feel, and yaw.
	On	97-98	Warning: None. Stall: No comment.	130 on final 120 over fence 110 touchdown	Good safe approach. Wouldn't slow down to 100 for touchdown because of lack of stall warning. Not bothered by being below suction-off stall speed due to low altitude. Appreciated available g in pattern.
H	Off	100	Warning: Yaw not noticed. Buffet at 120, wallows at 110. Stall: Satisfactory. Partially stalled at 120 to 110.	130 on final 120 over fence 110-115 touchdown	Adequate speed for flare without stall.
	On	96	Warning: Very light buffet 102 mainly in rudder. Stall: Acceptable. Abrupt roll-off.	115 on final 110 over fence 110 touchdown	115 limited by g available for round-out. (100 would be O.K. if power could be reduced. No worry about visibility down to 100. No worry about visibility below over-fence speed. Not bothered by suction-off stall speed. Appreciated additional g available in approach turn.
I	Off	110-115	Warning: Buffet 10 before stall. Stall: Good.	135	Proximity to stall.
	On	97-98	Warning: Little. Stall: Healthy left roll.	120	Rate of sink increasing plus power required to hold level flight. Lack of stall warning. Big difference in maneuvering at low speed suction on and off.
J	Off	114-121	Warning: Yaw-buffet down to 114. Wallows 121-114.	145-140	Proximity to yaw. Speed above stall O.K. at 140
	On	95	Warning: Slight yaw and buffet. Stall: Good. Small roll-off.	120	Attitude too steep below 120-115. Nose too high. Speed above stall O.K. but worried about effects of decreasing power in making approach.
K	Off	115	Warning: Satisfactory. Stall: Satisfactory.	130	Proximity to yawing tendence at 125.
	On	95	Warning: Unsatisfactory, none. Stall: Satisfactory.	110	Visibility. Ability to pull g and maneuver markedly improved over other configuration.
L	Off	115	Warning: Satisfactory. Yaw and roll at 125. Stall: Satisfactory. Straight ahead, controllable.	130	Abrupt yaw at 125.
	On	92	Warning: Unsatisfactory. None. Stall: Satisfactory. Mild pitch-up and slight left roll.	115	Nose-high attitude.
M	Off	100	Warning: Marginal. Yaw at 125. Stall: Satisfactory. Recovering: Unsatisfactory, due to large altitude loss.	140 on base 130 over fence 120 touchdown	Proximity to yaw. Proximity to stall.
	On	88	Warning: Marginal. Lateral instability at 90. Stall: Marginal.	115-120 105 minimum on final	Positive altitude control.
N	Off	108	Warning: Unsatisfactory. Abrupt yaw at 121. Stall: O.K.	140 on base 135 over fence 130 touchdown	Adequate margin above yaw.
	On	90	Warning: Unsatisfactory. None. Stall: Marginal.	110	Comfortable feel. Climb capability without power addition.
O	Off	121	Warning: None. Stall: Moderate left roll. Satisfactory.	130 on base 125 over fence 120 touchdown	Buffet in maneuvering onto final turn.
	On	98	Warning: None. Stall: Abrupt roll-off, but tolerable.	115 on base 112 over fence 108 touchdown	Deterioration of lateral control (unable to correct for gusts).
P[1]	Off	Not reported	No comment.	130	Proximity to yaw.
	On	100	No comment.	108	Proximity to stall.

[1]General comment: Reduction in stalling speed is of primary importance in reducing approach speed. Decrease in attitude is secondary.

TABLE II.- STALL DATA - LANDING-APPROACH CONFIGURATION

Pilot	I. Standard F-86A-1; 38° flap; slats			II. F-86A-5; 55° suction flap; C.L.E. plus fence					
				Suction off			Suction on		
	V_S, knots (1)	Opinion of warning	Opinion of stall	V_S, knots (1)	Opinion of warning	Opinion of stall	V_S, knots (1)	Opinion of warning	Opinion of stall
A	91-95	Satis-factory	Satis-factory	99	Weak	Satis-factory	99	Weak	Satis-factory
B	91	Marginal	--do.----	99	Adequate	--do.----	93-96	Adequate	--do.----
C	---	---	---	99	---	--do.----	92	---	Good
D	---	---	---	99	---	--do.----	98	---	Satis-factory
E	97	No warning	---	96	---	--do.----	95	None	--do.----
F	90-96	Insuffi-cient	Satis-factory	89-95	Good	--do.----	87-91	Inade-quate	--do.----
G	93	---	Good	100	Satis-factory	--do.----	98	Satis-factory	--do.----
H	95	Good	---	97	--do.----	--do.----	91-95	---	--do.----
I	95	--do.----	Good	99-100	Good	---	96	Good	---
J	---	---	---	99	---	---	95	Adequate	---
K	95	---	Satis-factory	94	---	Satis-factory	90	---	Satis-factory
L	95	---	--do.----	94	Satis-factory	--do.----	90	Marginal	--do.----
M	96-97	---	Unsatis-factory	93-95	Marginal	--do.----	89-93	--do.----	--do.----
N	96	Unsatis-factory	Satis-factory	97	--do.----	Good	97	--do.----	Good
O	---	---	---	96	---	--do.----	89	---	--do.----
P	---	---	---	99	---	Satis-factory	97	---	Satis-factory
Average pilot's calibrated stall speed	94.6	Unsatis-factory to good	Satis-factory to good	97.1	Marginal to satis-factory	Satis-factory	94.0	Marginal	Satis-factory to good
Measured stall speed $V_{C_{L_{max}}}$ for $\left(\frac{W}{S}\right)_A$	88.5	---	---	93.9	---	---	92.9	---	---

Pilot	III. F-86F; 38° flap; suction leading edge					
	Suction off			Suction on		
	V_S, knots	Opinion of warning	Opinion of stall	V_S, knots (1)	Opinion of warning	Opinion of stall
A	111	Unsatis-factory	Satis-factory	88	---	Marginally satis-factory
B	105	---	---	88-91	Unsatis-factory	---
C	97	Fair	Satis-factory	88-90	---	Satis-factory
D	98-112	---	Accept-able	92	None	Accept-able
E	102	---	Satis-factory	95	---	Satis-factory
F	104	---	Unsatis-factory	95	None	---
G	104	Good	---	95-96	None	---
H	97	---	Satis-factory	94	---	Acceptable
I	106-112	---	Good	94-95	Little	---
J	110-118	---	---	93	---	Good
K	111	Satis-factory	Satis-factory	92	Unsatis-factory	Satis-factory
L	111	--do.----	--do.----	90	--do.----	Do.
M	98	Marginal	--do.----	86	Marginal	Marginal
N	105	Unsatis-factory	--do.----	88	Unsatis-factory	Do.
O	118	None	--do.----	96	None	Tolerable
P	---	---	---	97	---	---
Average pilot's calibrated stall speed	106.4	Unsatis-factory to good	Satis-factory	91.6	Unsatis-factory	Marginally satis-factory
Measured stall speed $V_{C_{L_{max}}}$ for $\left(\frac{W}{S}\right)_A$	107.2	---	---	85.0	---	---

(1) Extrapolation of the airspeed calibration curves of figure 5 has been required for some of these values.

TABLE III.- APPROACH SPEEDS OR OVER-THE-FENCE SPEEDS CHOSEN IN INITIAL INVESTIGATION

Configuration	Suction	Calibrated approach speed in knots for each pilot: A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Average
I. Standard F-86A-1; 38° flap; slats	---	114	114	---	---	118	114	118	130	125	---	118	118	114	114	---	---	117.9
II. F-86A-5; 55° suction flap; C.L.E. plus fence	Off	115	115	126	121	115-121	115	121	115	126	121	115	115	105-110	110-115	115	108	116.0
	On	115	108	115	121	105	110	115	110	115	115	108	105-107	99-105	110-115	110	104	110.8
III. F-86F; 38° flap; suction leading edge	Off	134	139	127	129	123	123-129	129	117	134	139-144	129	129	129	134	123	129	129.5
	On	103-105	107	117	107	107	107	117	107	117	117	107	112	103	107	109	105	109.4
Decrease in approach speed due to added flap deflection	---	-1	-1	---	---	+3--2	-1	-2	15	-1	---	3	3	4-9	+4--1	---	---	2.1
Decrease in approach speed due to addition of flap B.L.C.	---	0	7	11	0	10-16	5	6	5	11	6	7	8-10	5	0	5	4	5.9
Decrease in approach speed due to addition of leading-edge B.L.C.	---	29-31	32	10	22	16	16-22	12	10	17	22-27	22	17	26	27	14	24	20.2
Decrease in approach speed due to leading-edge B.L.C. compared to standard F-86A-1	---	9-11	7	---	---	11	7	1	23	8	---	11	6	11	7	---	---	9.3

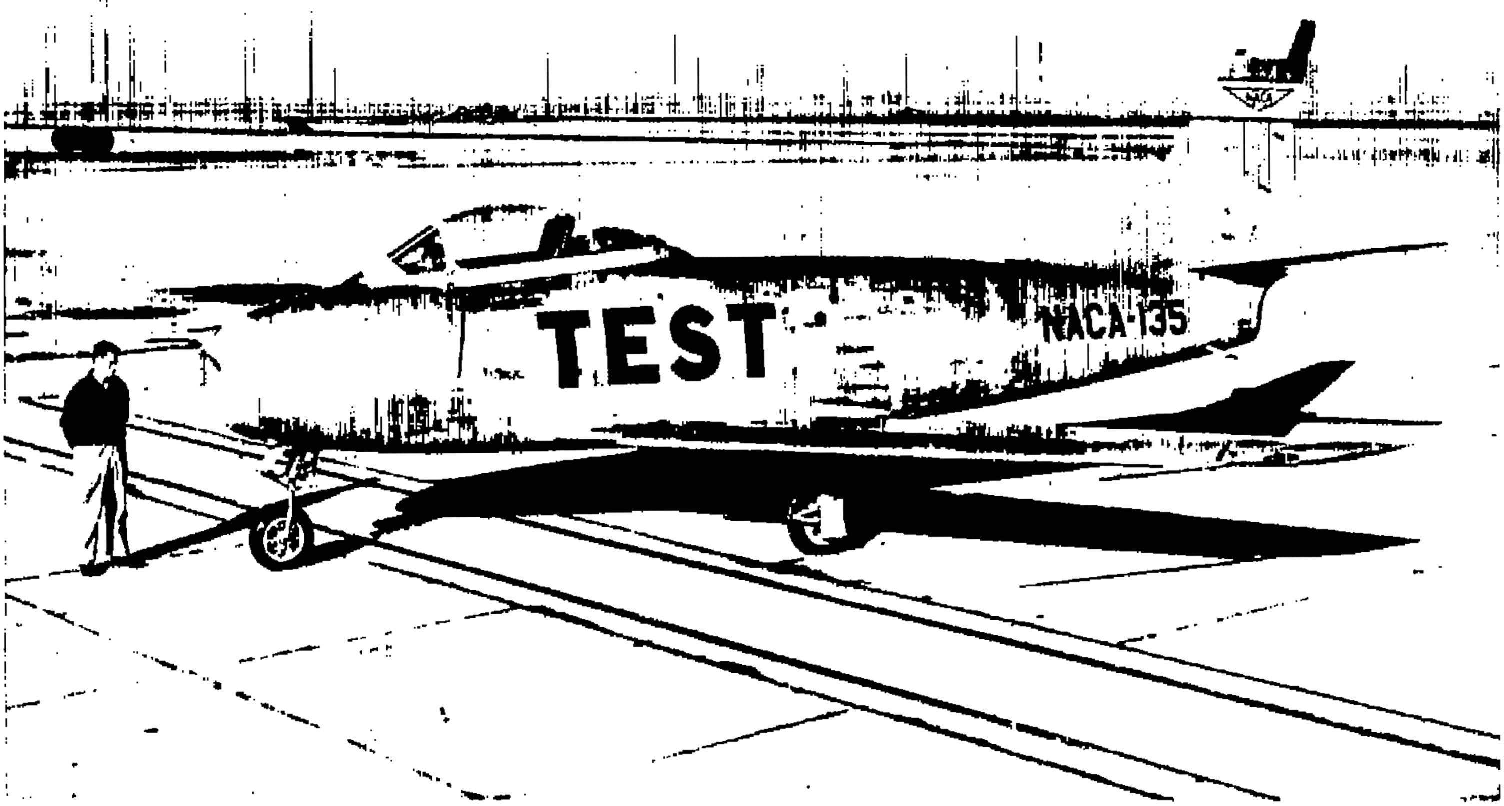
TABLE IV.- PRIMARY REASONS FOR LIMITING APPROACH SPEEDS

Category	Reasons	Initial investigation: I. Standard F-86A-1; 38° flap; slats	II. F-86A-5; 55° suction flap; C.L.E. plus fence: Suction off	II. Suction on	III. F-86F; 38° flap; suction leading edge: Suction off	III. Suction on	Later investigation: IV-VII. F-86A; suction flap (all configurations): Suction on or off
A	Proximity to stall	B	A, D, G, H, J, N, P	A, B, D, G, I, J, N, P	D, B, I, M	P[1]	
	Proximity to yaw				A, E, F, G, J, K, L, M, N, P		
	Poor stall characteristics			F		A, G, I	
	Number of pilots limiting because of stall characteristics	1	7	8	13	4	
B	Visibility	A, B, E, H, I	B, E, L	E, L		D, B, E, L	
	Attitude	A, I	I, J			A, J, K	
	Concern for dragging tail			E		F	
	Number of pilots limiting because of attitude or visibility characteristics	5	5	2		8	
C	Minimum positive longitudinal or altitude control	F, K, L, M, N	C, K, L	C, K, L	C	M, N	K, L, M, N
	Ability to flare, maneuver or arrest sink	F	F, M, O	M, O	H, O	H	K, L, M, N
	Increased rate of sink					I	
	Feel	G, H		H	G	N	
	Number of pilots limiting for altitude or longitudinal control characteristics	7	6	6	4	4	4
Deterioration of lateral control						O	
Concern for possible loss of suction						F, J	

[1]Pilot did not completely stall airplane.

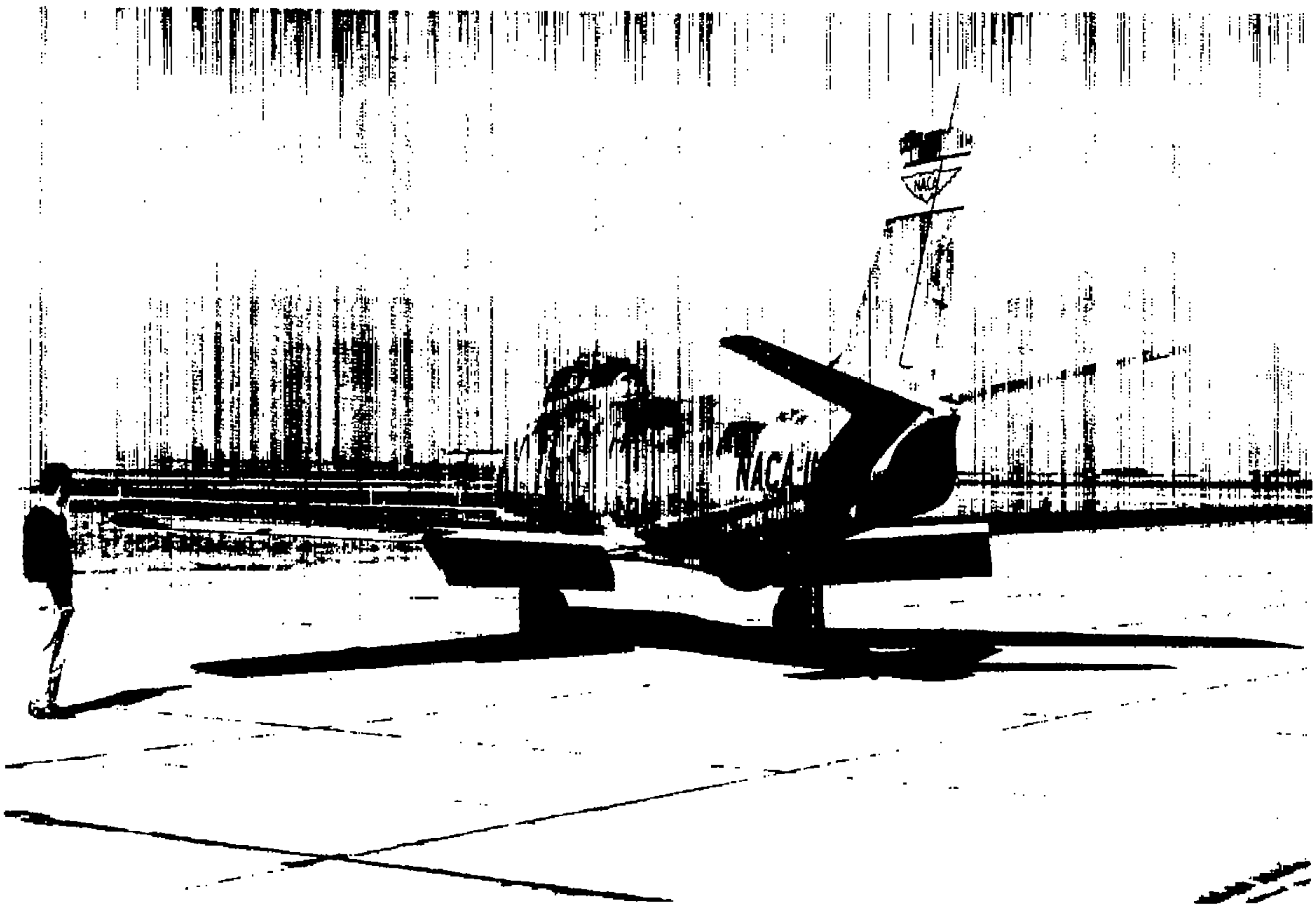
TABLE V.- COMPILATION OF CALIBRATED LANDING-APPROACH AIRSPEED DATA ON ALL CONFIGURATIONS FOR THE PILOTS FLYING THE COMPLETE EVALUATIONS

Pilot	Initial investigation					Later investigation							
	Configuration I. Standard airplane	Configuration II. 55° flap; C.L.E. plus fence		Configuration III. Suction leading edge		Configuration IV. 55° flap; C.L.E. no fence		Configuration V. 55° flap; slats		Configuration VI. 64° flap; C.L.E. and fence		Configuration VII. 64° flap; slats	
		Suction		Suction		Suction		Suction		Suction		Suction	
		Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
K	118	115	108	129	107	110	101-105	110	101-105	110	102	105	100
L	118	115	105-107	129	112	115	108	112	105	115	107		
M	114	105-110	99-105	129	103	105	99	105	95-100	110-112	99-105	105-110	100
N	114	110-115	110-115	134	107	110-115	105	107-108	102-105	108-110	102	105	100-102
Average pilot's calibrated approach speed, knots	116.0	112.5	107.1	130.2	107.2	110.6	103.7	108.6	102.2	111.2	103.2	105.8	100.3
Average decrease in approach speed due to added flap deflection, knots	---	3.5				5.4		7.4		4.8		9.5	
Average decrease in approach speed due to addition of suction B.L.C., knots	---	5.4		23.0		6.9		6.0		8.0		5.5	
Average decrease in approach speed below standard airplane, knots	---	8.9		8.8		12.3		13.4		12.8		15.0	
Measured stall speed $V_{C_{L_{max}}}$ for $(W/S)_A$, knots	88.5	93.9	92.9	107.2	85.0	85.3	82.1	90.2	88.4	91.7	89.4	89.3	87.3
Ratio of average approach speed to measured stall speed, knots	1.31	1.20	1.15	1.21	1.26	1.30	1.26	1.20	1.16	1.21	1.16	1.19	1.15
Decrease in speed for minimum thrust required due to suction B.L.C., knots	---	6.3		10.0		---		8.0		6.7		7.0	



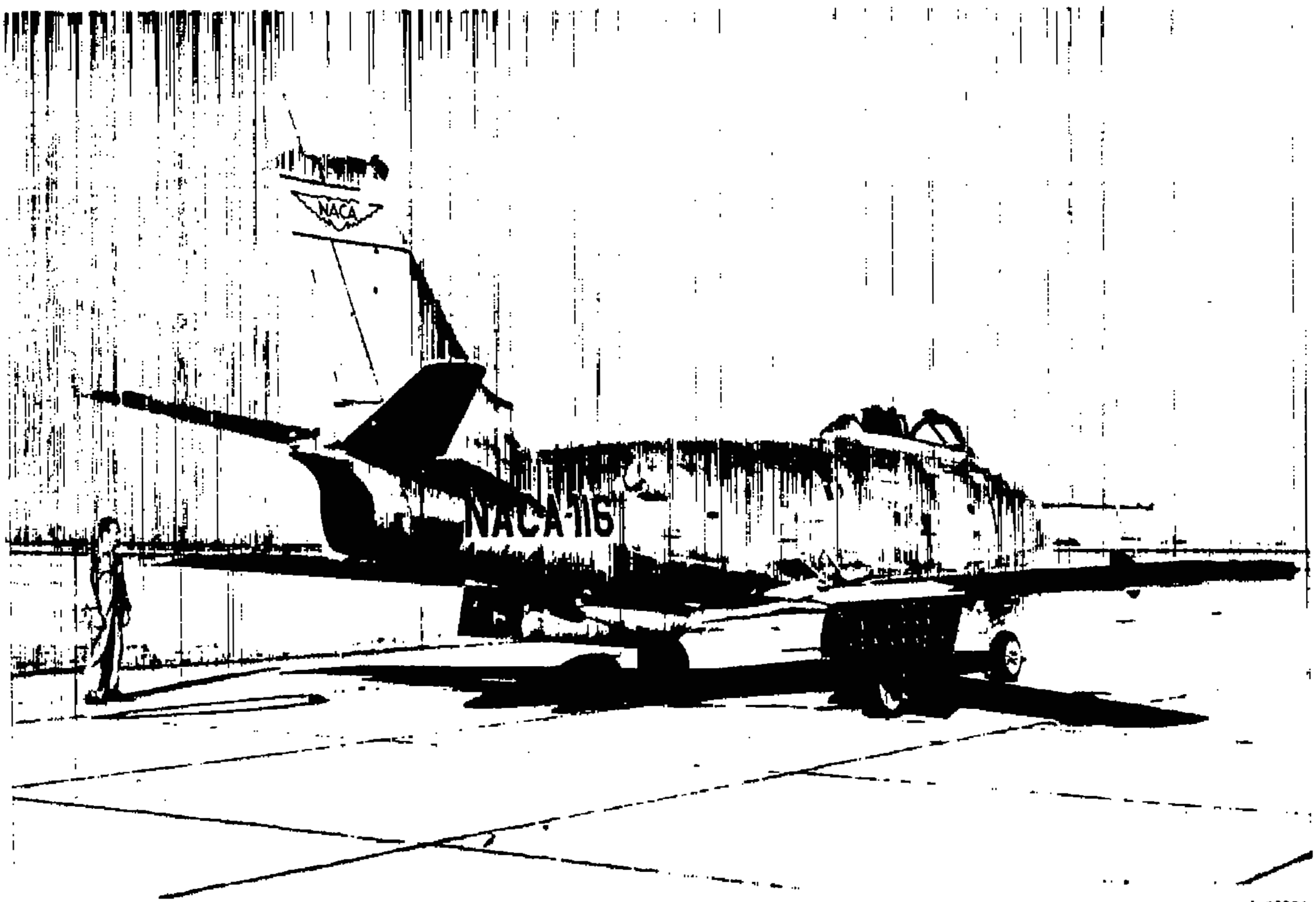
A-19983

Figure 1.- Standard F-86A-1 airplane.



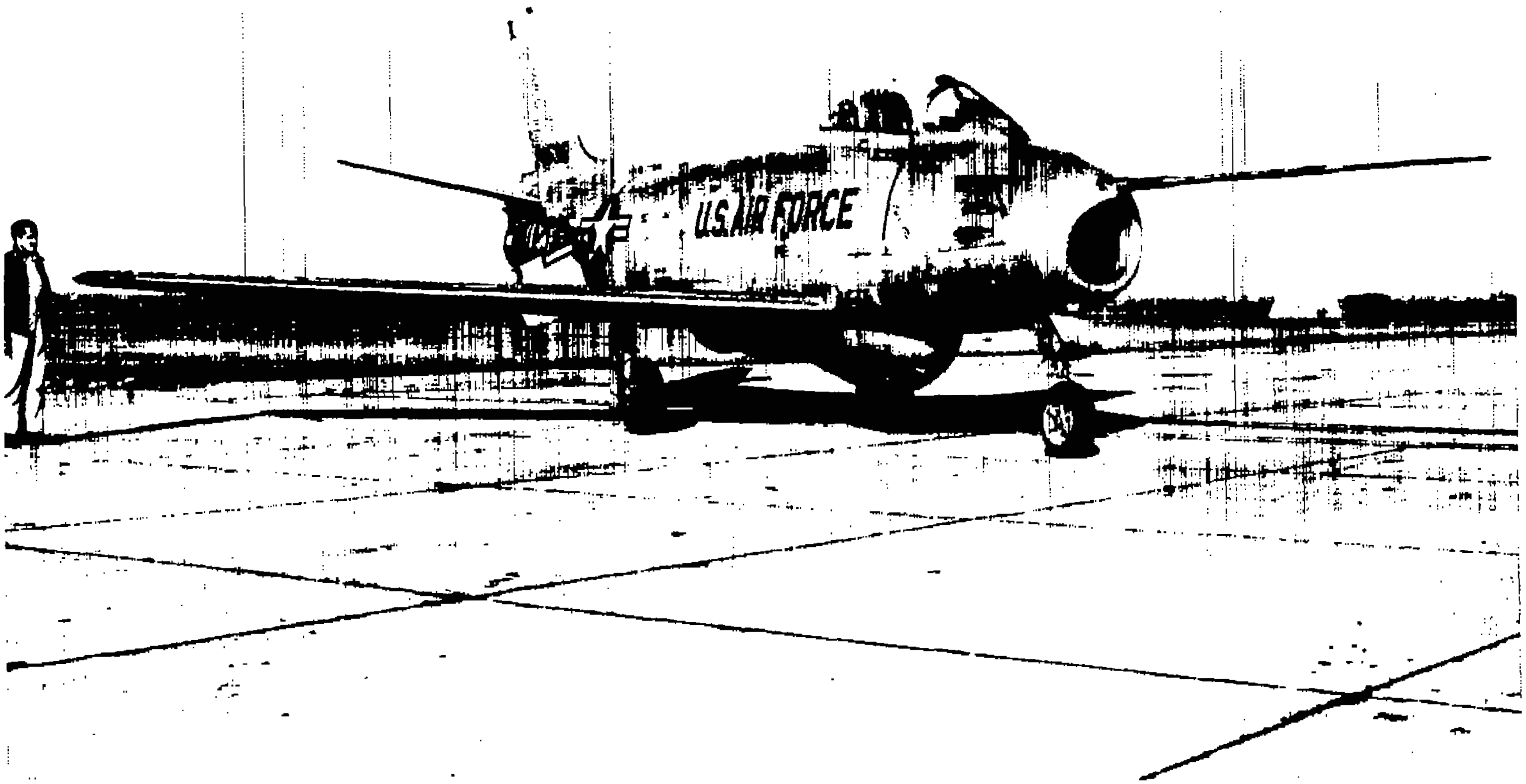
A-20150

Figure 2.- The F-86A-5 airplane equipped with a 55° suction flap, cambered leading edge plus fence.



A-19984

Figure 3.- The F-86A-5 airplane equipped with 64° suction flap, cambered leading edge plus fence. (Diffuser, graded porous material, and other improvements added.)



A-19919

Figure 4.- The F-86F airplane equipped with a suction leading edge.

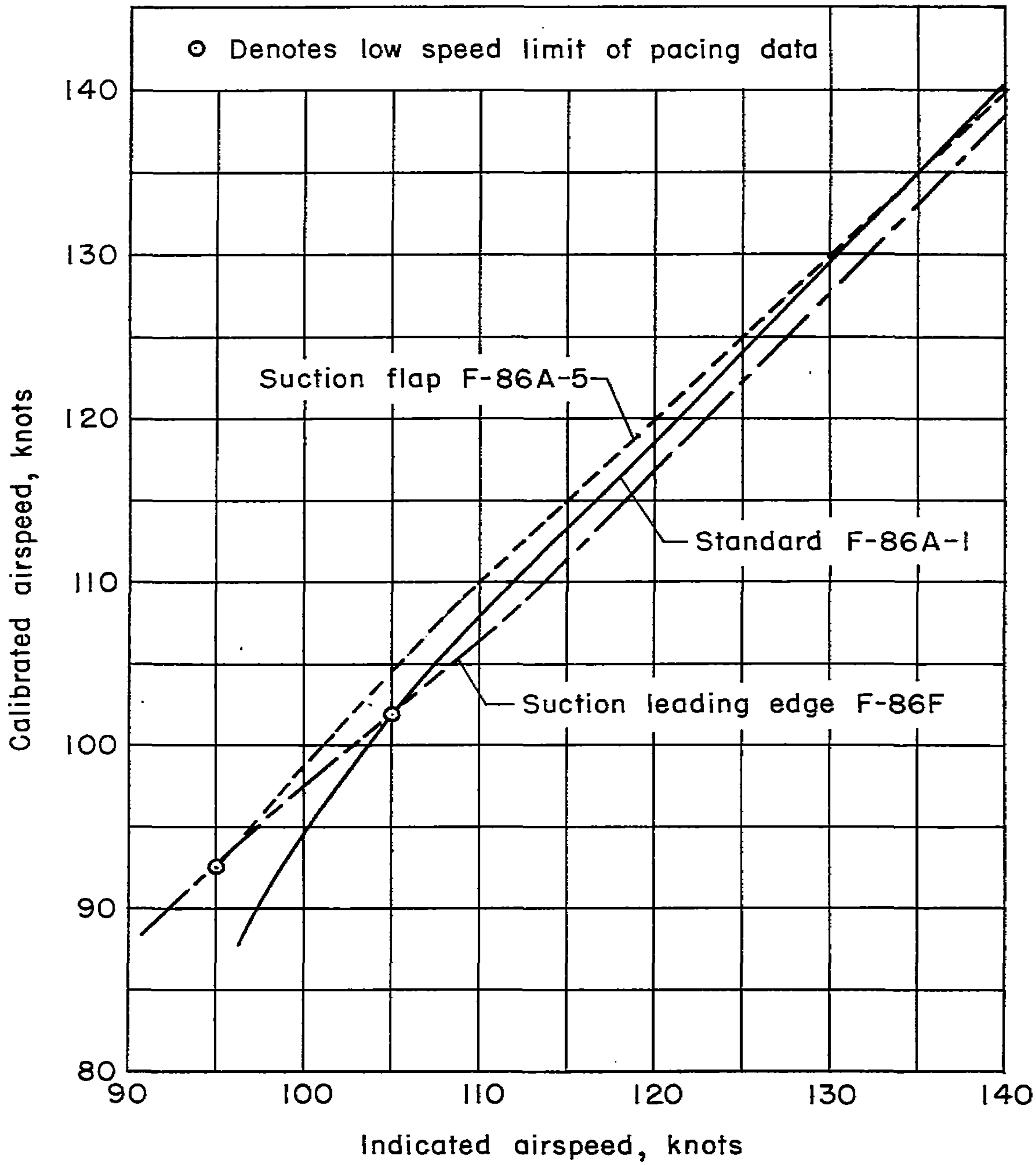
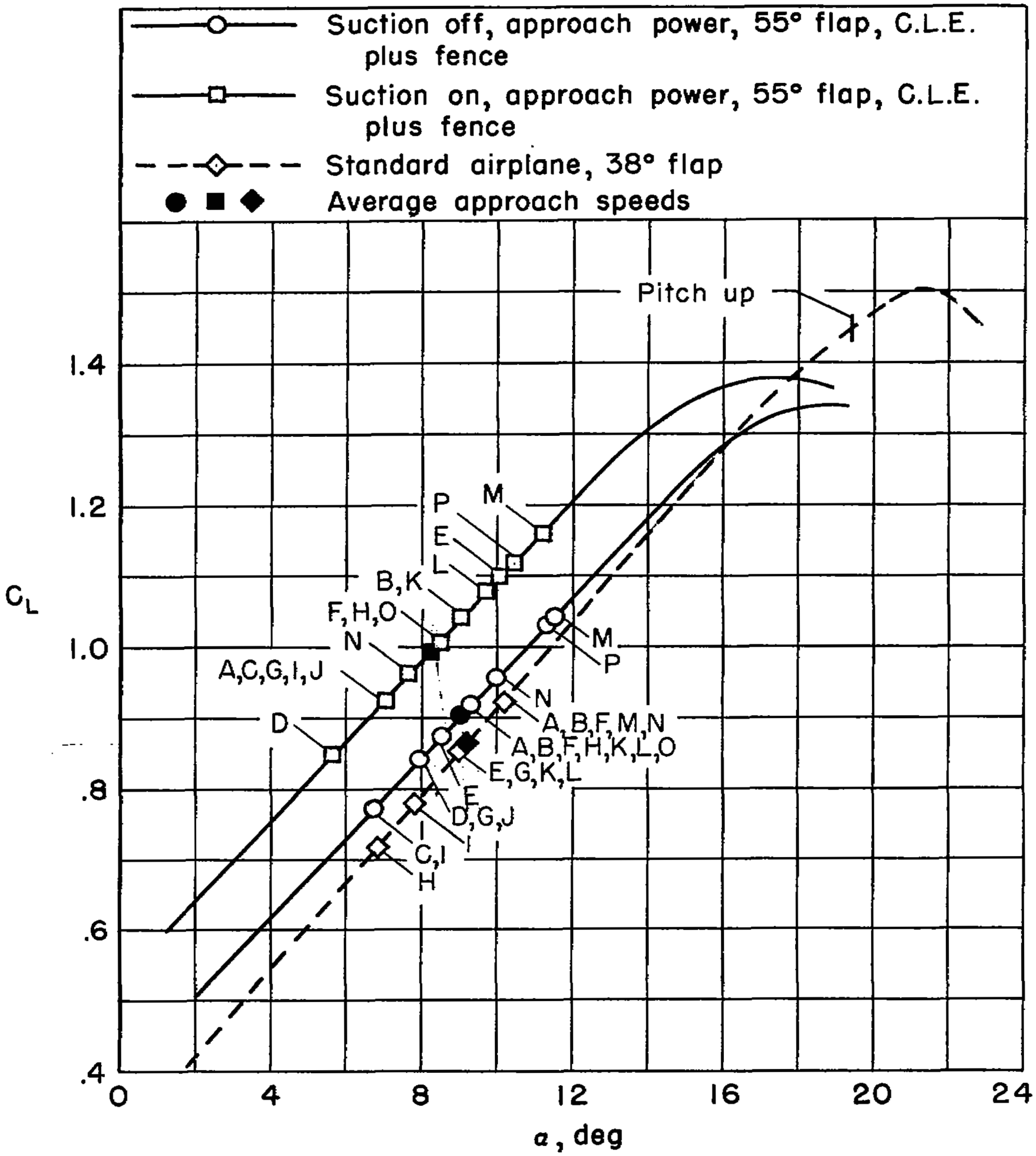
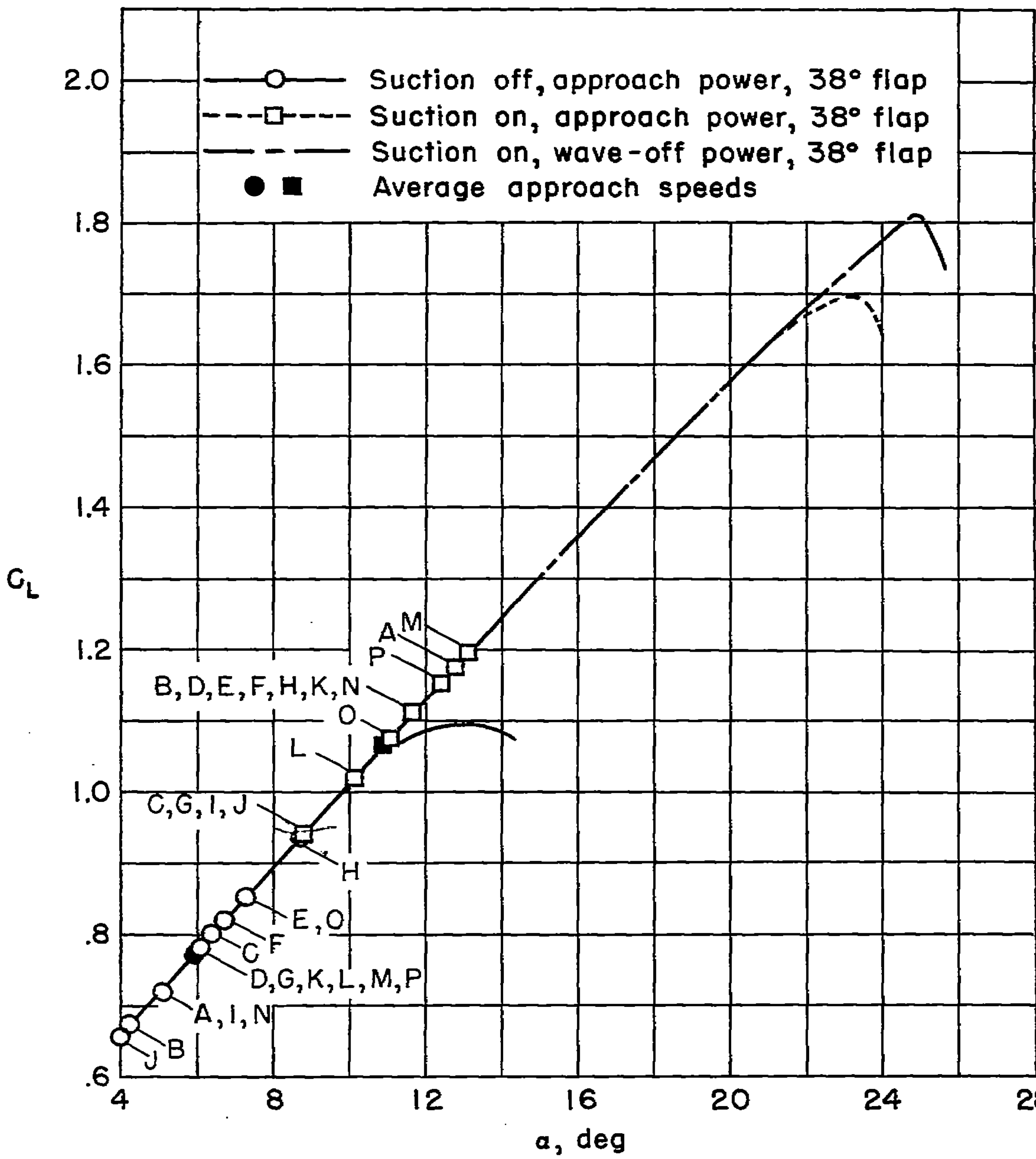


Figure 5.- Flight-determined airspeed calibration curves for the test airplanes.



(a) Suction-flap airplane.

Figure 6.- Lift coefficient versus angle of attack for the test airplanes with values corresponding to individual pilot's approach speed shown.

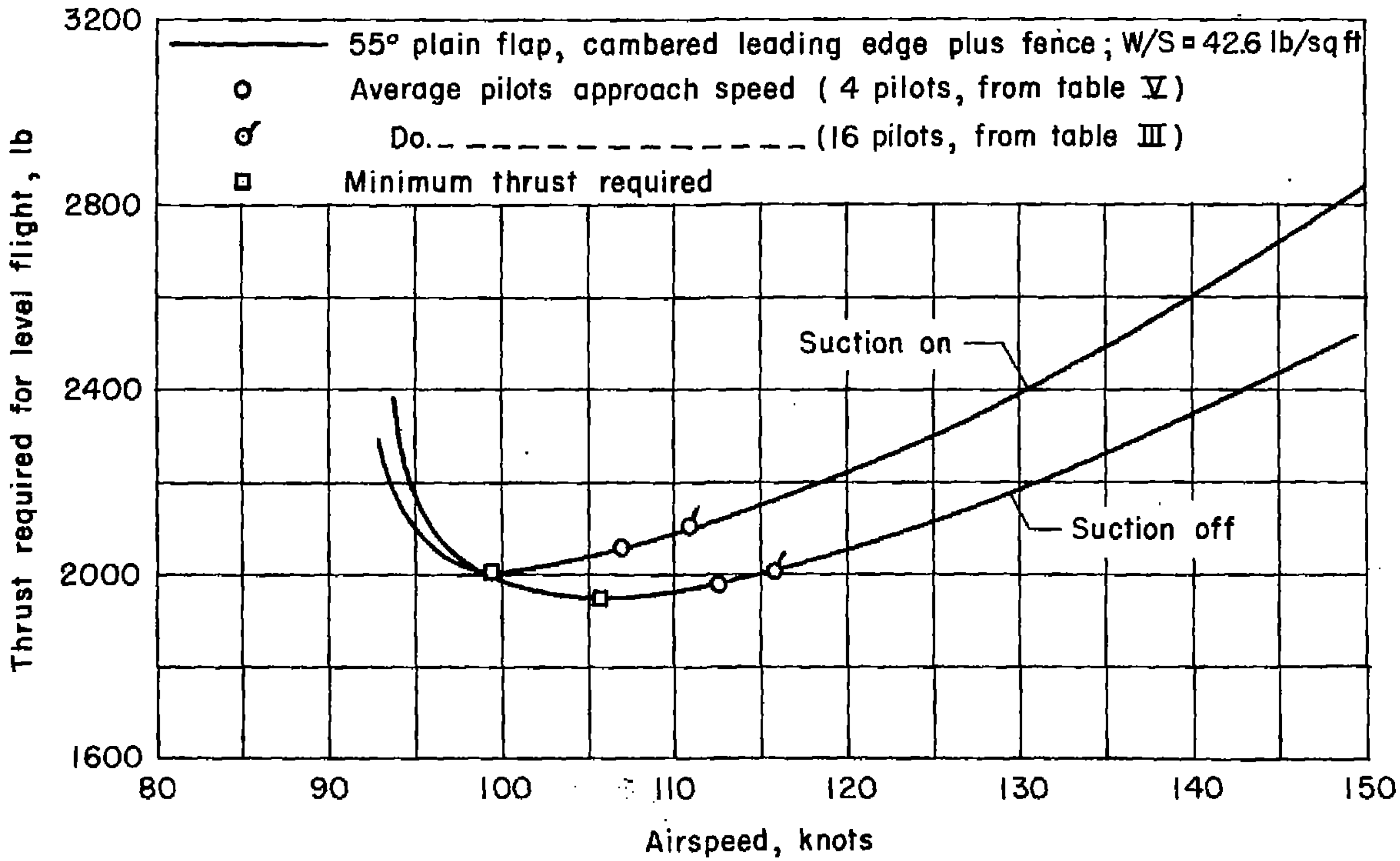


(b) Suction leading-edge airplane.

Figure 6.- Concluded.

[redacted]

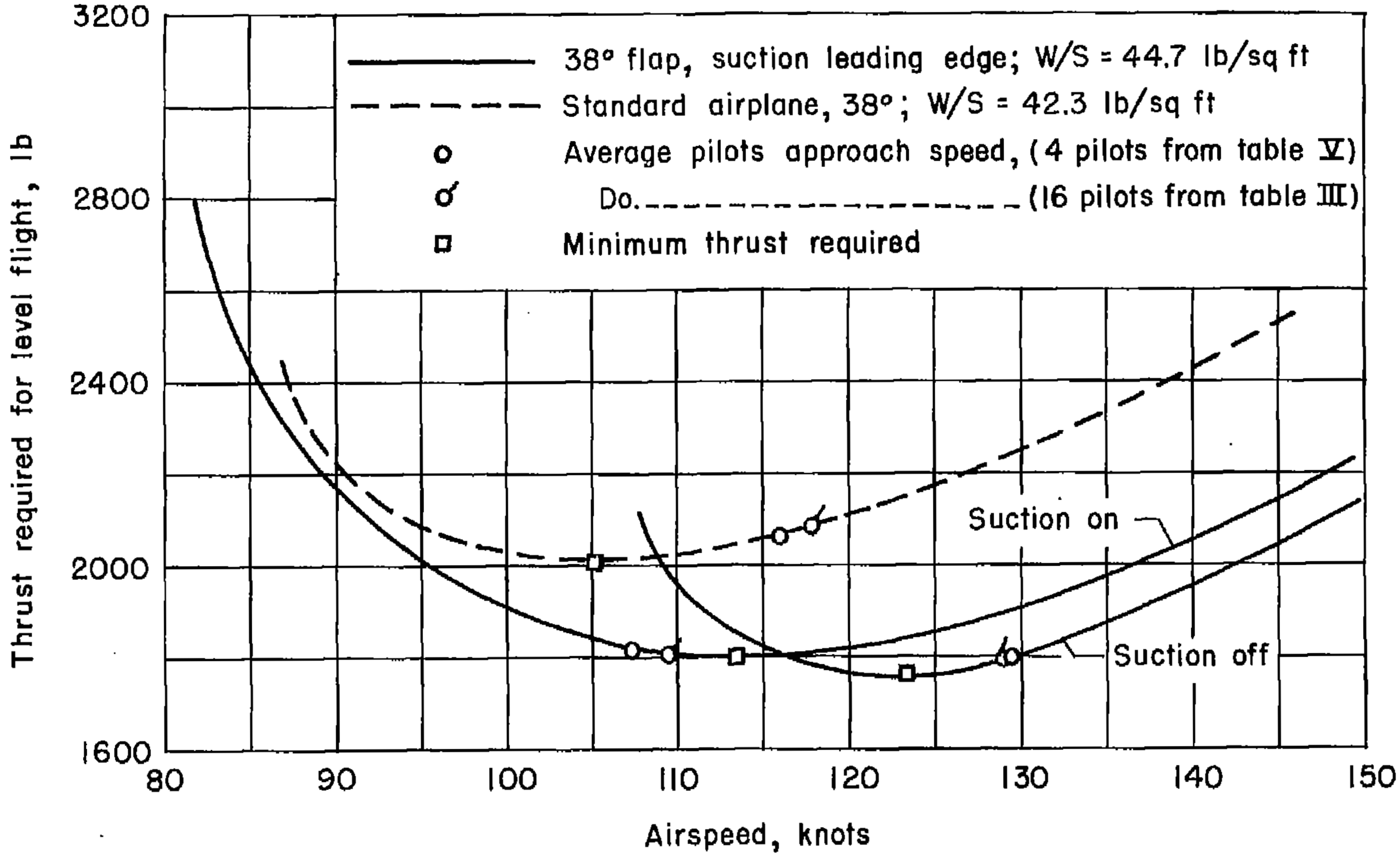
[redacted]



(a) Suction-flap airplane.

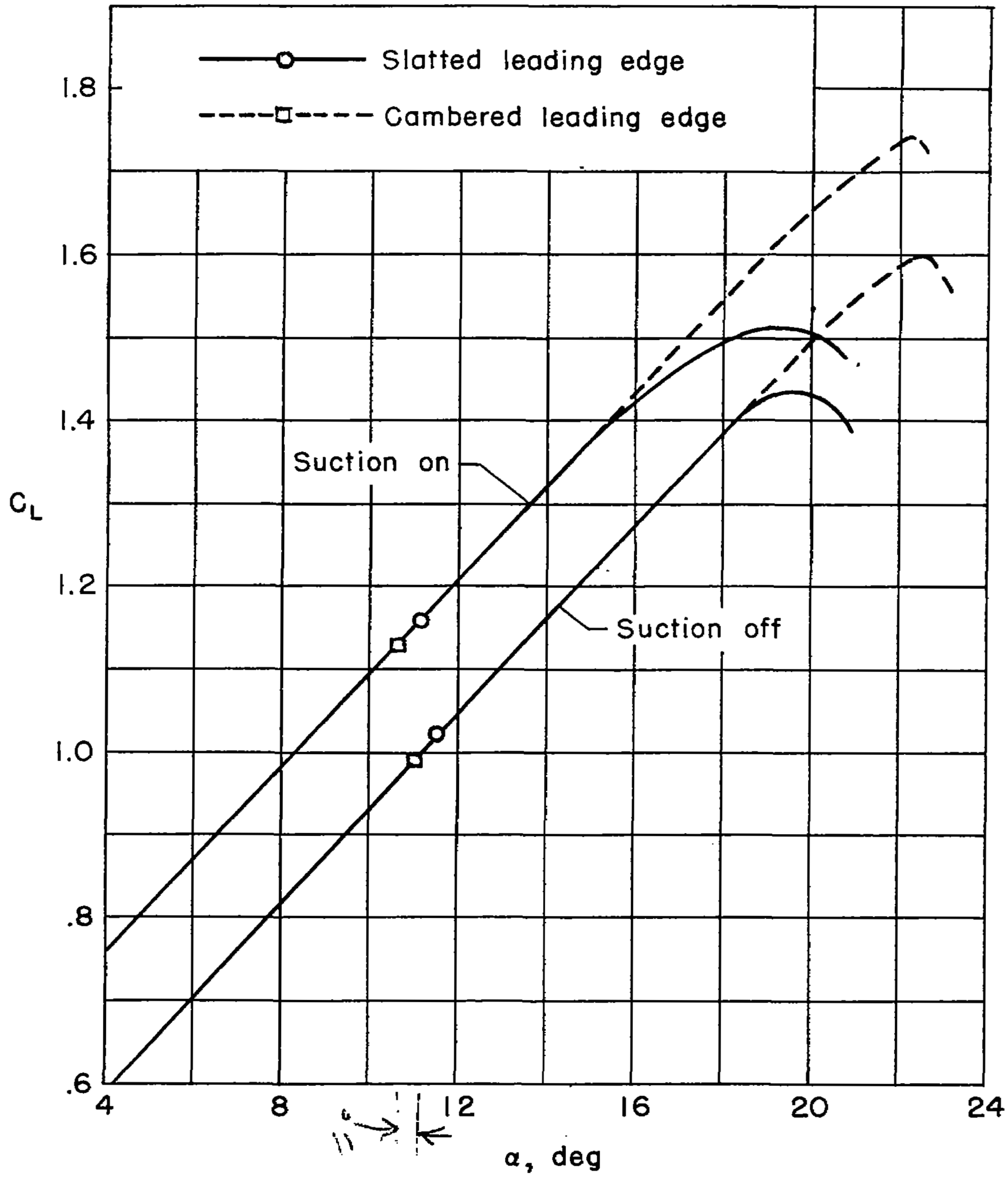
Figure 7.- Thrust required versus airspeed for the test airplanes; flap and gear down; speed brakes out.

[redacted]



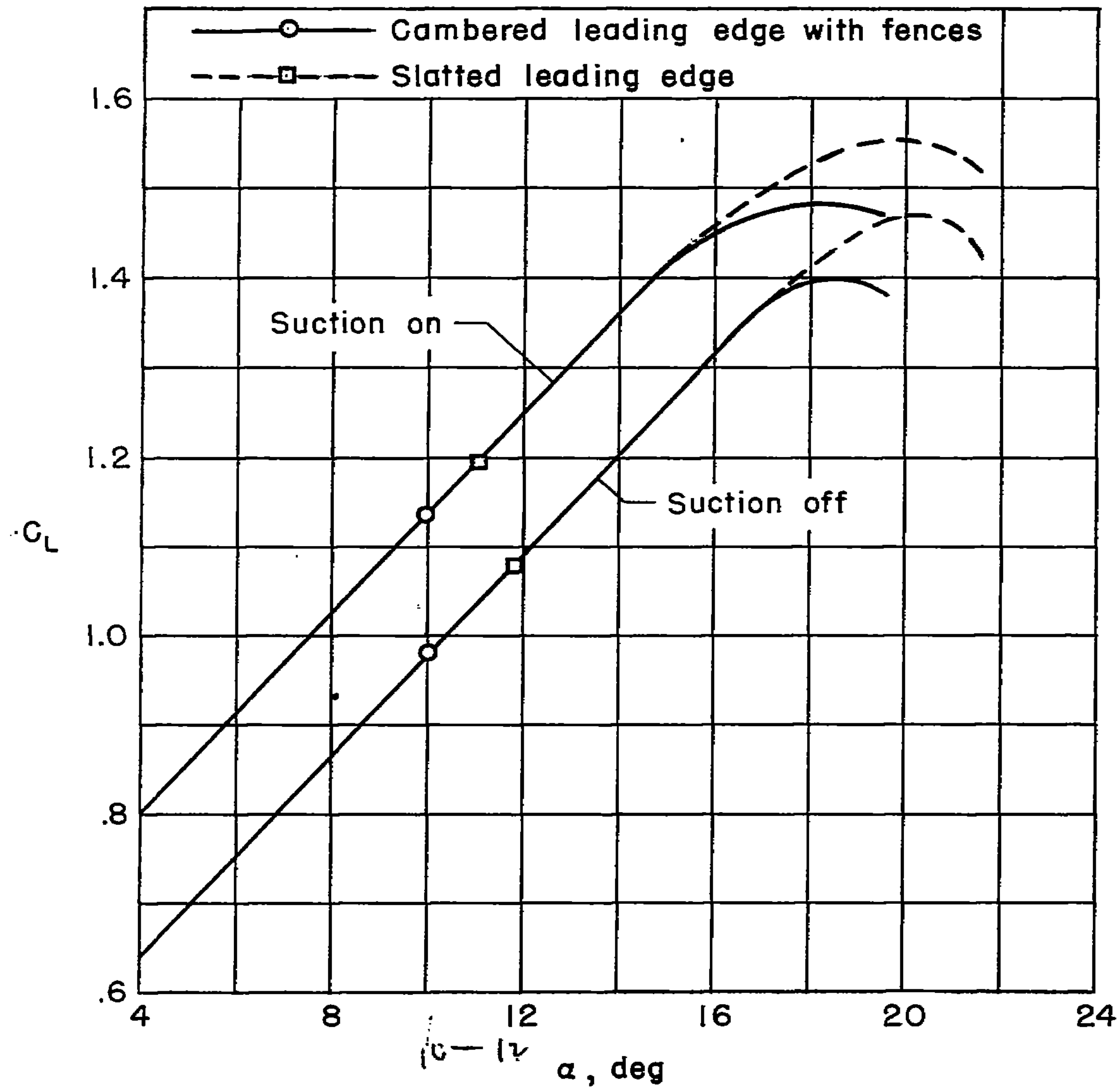
(b) Suction leading-edge airplane.

Figure 7.- Concluded.



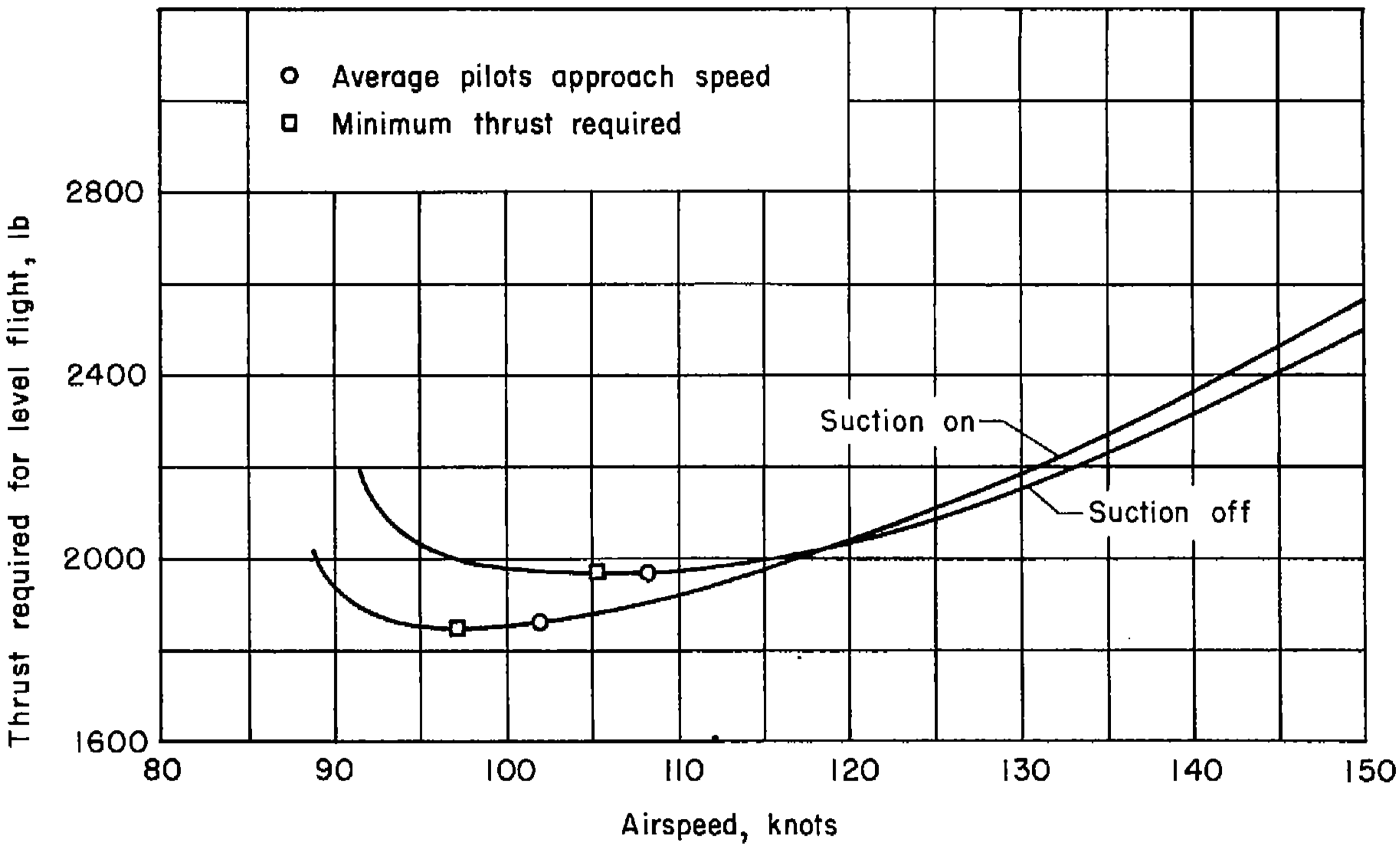
(a) The 55° plain flap.

Figure 8.- Lift coefficient versus angle of attack for the improved suction-flap airplane with several leading-edge configurations with values corresponding to average pilots' approach speeds shown.



(b) The 64° plain flap.

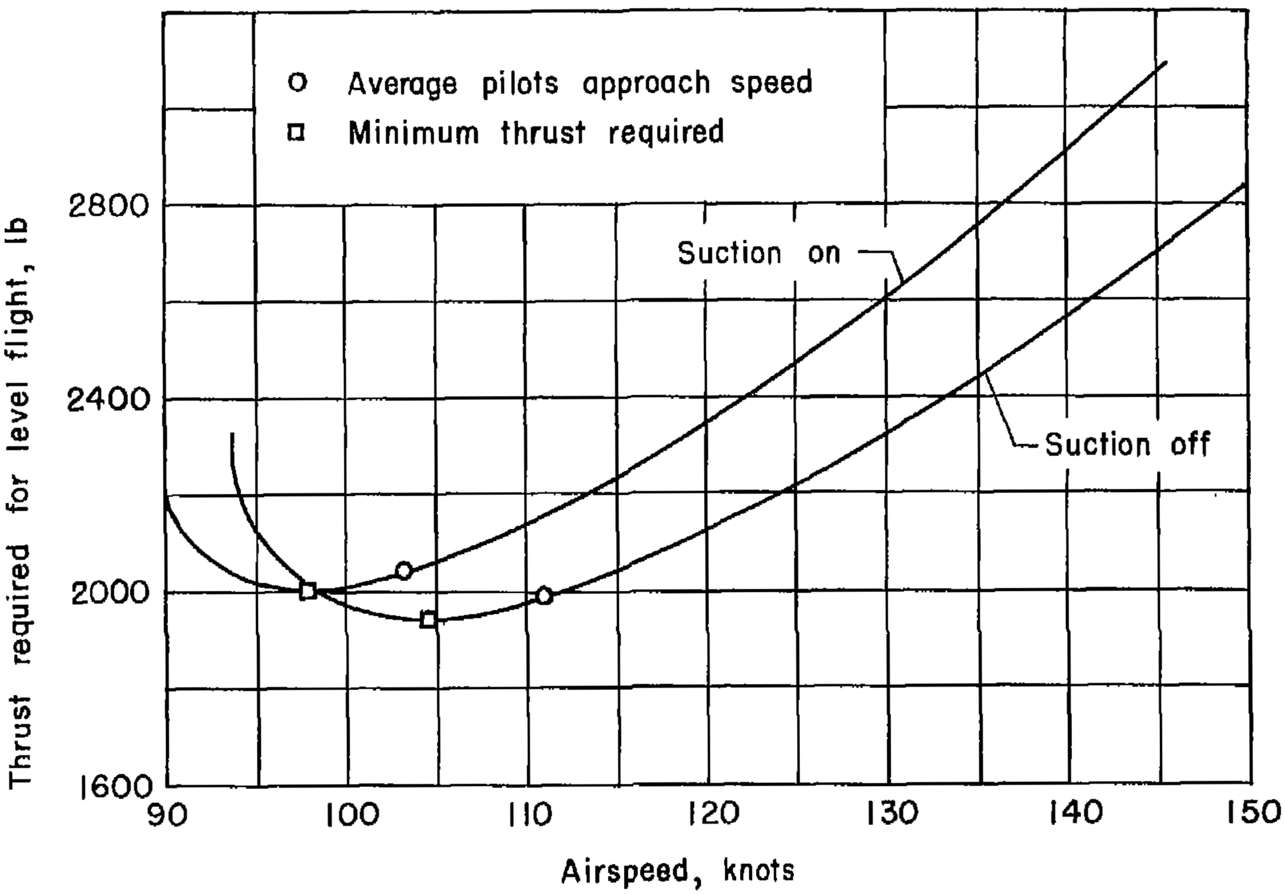
Figure 8.- Concluded.



(a) The 55° plain flap, slatted leading edge.

Figure 9.- Thrust required for level flight versus airspeed for the improved suction-flap airplane with several leading-edge configurations, flap and gear down, speed brakes out; W/S = 42.6 pounds per square foot.

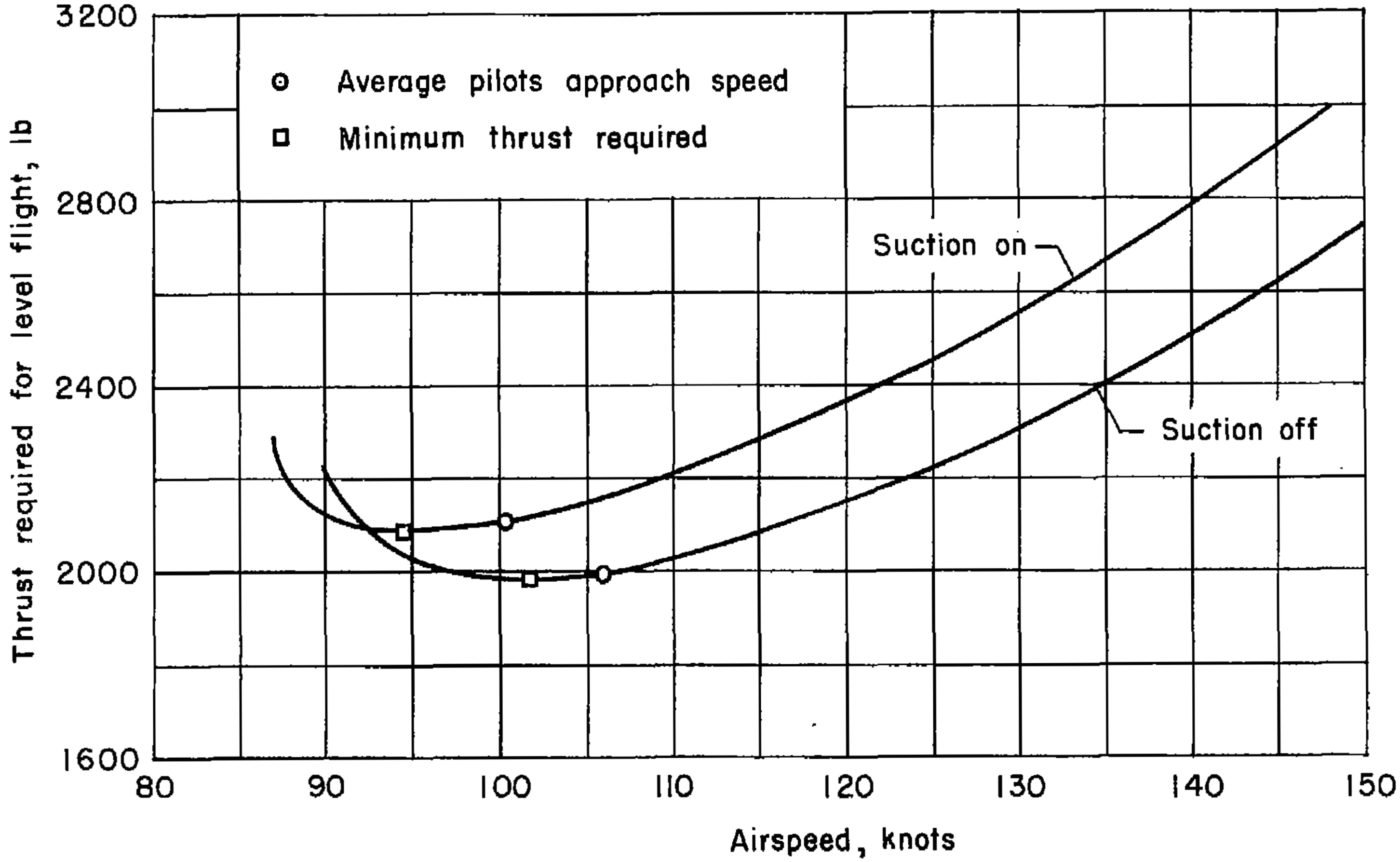
[redacted]



(b) The 64° plain flap, cambered leading edge with fence.

Figure 9.- Continued.

[redacted]



(c) The 64° plain flap, slatted leading edge.

Figure 9.- Concluded.

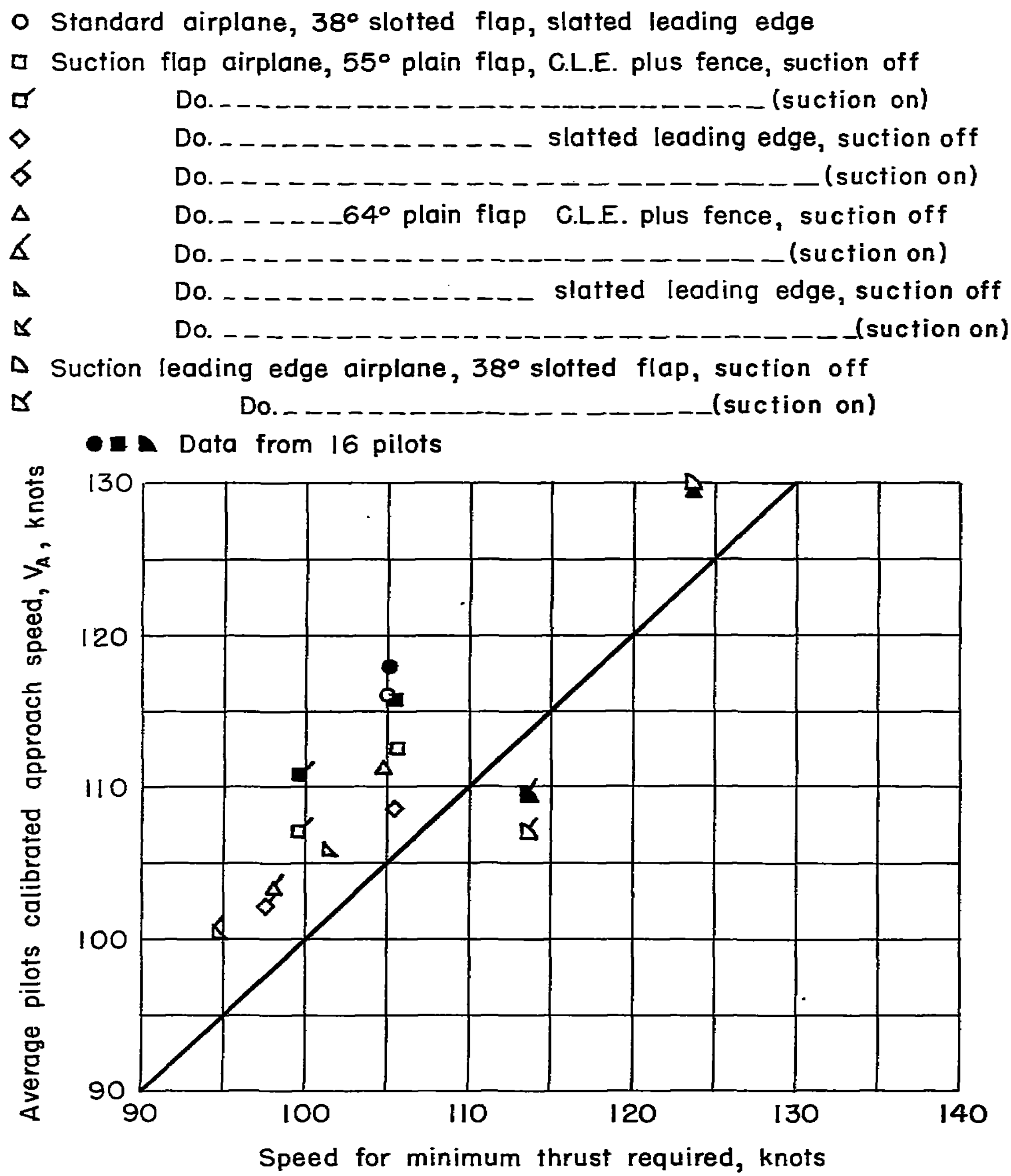


Figure 10.- Pilots' approach speed versus speed for minimum thrust required (pilots K, L, M, N except as noted).

NACA - Langley Field, Va.